Thesis Updates & Reading
MSc Ocean Physics, University of Victoria

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December 17, 2020

Contents

1 Meetings

1.1 September 13th, 2019

- **Work**:
  - Meeting with Steve Mihaly 1:30pm Friday @ ONC
  - Read Alford et al (2012) and review references (Pinkel, Mihaly)
  - Obtain a sample data set and create a time series for last year (average between hours)
  - Plot u, v, w
  - Install Python modules: NetCDF4, xarray, dask
  - conda install
  - import xarray as xr with xr.open_dataset('data.nc') as ds print(ds)
  - ds.time for variables, etc.
  - tab completion with Jupyter
  - ONC data: Backscatter? Echo intensity? Error in velocity?
- **To do**:
  - Initial plots (scales) for all three sites, monthly data (July and January)
  - Note any issues for ONC

1.2 October 15th, 2019

- **Work**:
  - No Axis July data, 2019
  - Plots for Mideast 150 kHz, July / January 2018; Upper Slope 75 kHz, July / January 2018; Axis 75 kHz, January 2018
  - Questions:
  - Explain 'line magic'
  - xarray for data visualisation
  - reverse depth for plots
  - vmin and vmax optimal values
- **To do**:
  - Basic filtering: single depth, remove average
  - Wind correlation: Johannes (DFO La Perouse data)
  - Ed for DNS access from home
  - Beam doppler values to Steve for troubleshooting
  - Low-pass 30h filter to remove tides
  - Read Thomson/Mihaly for west coast currents, copy methods
  - Total data − filtered data = residual data
  - Notebook for results, publish to GitHub

Reading Notes – Oct. 4$^{\mathbf{th}}$:

Alford *et al* (2012) - Annual Cycle and Depth Penetration of Wind-Generated Near Inertial Internal Waves at Ocean Station Papa in the Northeast Pacific

Near-inertial internal waves are one of two processes that dominate the internal wave band, along with internal tides, and are typically the result of passing storms. They are likely responsible for much of the mixing in the deep ocean, through a cascading effect of kinetic energy flux that reaches into, and then well beyond the mixed layer. Most of this energy is imparted in discrete energetic events (storms, through dissipation, and vertical and lateral propagation), prominently in the winter, that partition into vertical modes upon descent. Findings show a significant portion of wave groups propagating downwards beyond 800m. Analysis shows internal wave motions dominating the two-year energy spectra (83%), with near-inertial frequencies accounting for 47% (and energies accounting for up to 33% of wind work observable in surface layers). These quantities, relative to stratification estimates, suggest near-inertial internal waves are likely an important source of energy in the deep ocean.

Questions :

- Barotropic (constant density along isopycnal) versus baroclinic (varied density along isopycnal) versus internal tides?
- Different modes simply different frequencies imparted by the passing storm?
- KHz rating for ADCPs?
- What is the importance of mixed layer depth (MLD)?
- Velocities strongly clockwise polarised due to Coriolis?
- Able to research most unfamiliar terms and concepts, but most confusion arises from the description of data processing techniques (such as fourth-order Butterworth filter). I expect this knowledge will largely arise with experience.

1.3 November 8th, 2019

- **Work**:
  - Optimise low-pass filter for tides, do not average for velocity profiles.
  - GitHub repository > kurtisanstey/project
  - Send beam doppler values to Steve Mihaly
- **To do**:
  - Wind data > 46139 La Perouse / Amphitheatre lighthouse / Tofino airport
  - SSH for DNS connection (Ed)
  - Hayley waves textbook
- **Questions**:
  - Real FFT units for y-axis
  - Real or combined Real and Imaginary FFT
  - PSD peaks correspond to tidal frequencies
  - Begin NSERC application

1.4 November 15th, 2019

- **Work**:
  - Optimise filter (40-hour Butterworth)
  - Log-log plots for PDS
  - Jupyter widgets integrated
  - Improve PDS
  - Interpolate for NaN values, set depth range to avoid noise at range extent
  - Add markdown to Notebooks for comments
  - Filtered and residual data comparison, write a for loop to do this for each depth
- **To do**:
  - Wind data (Ed network / Tofino airport)
  - SSH for DNS connection (Ed)
  - Hayley waves textbook
  - Local tidal frequencies
  - Revise NSERC application

1.5 November 23rd, 2019

- **Work**:
  - Improve visual clarity of plots (comparison, scales, labels, etc.)
  - Use np.interp vs pandas
  - Add Jody's .bib file to Mendeley
  - Revise NSERC application
- **To do**:

- Add scholarly contributions to GitHub
- Fix Afficio entry on CV
- Further internal waves reading
- Lab work on Wednesday, 1:30pm

1.6 December 2nd, 2019

Wave tank with 2-layer (salinity based density difference) flow, generating internal waves over a submerged object, visible through the use of photodegradable dye.

1.7 December 16th, 2019

- **Work**:
  - Axis & Upper Slope v3 (opt. tide loop/general code)
  - Optimised filter and plots
- **To do**:
  - General reading: Surface waves, 2-layer waves, waves textbooks, continental slope papers
  - Suggested reading: Gemmrich, Klymak 2011, Turner, Thomson (Cali), Munk 1981, Kunze/Gregg 1991, Klymak/Pinkel 2008
  - Create summaries of papers and useful techniques
  - GM Toolbox
  - 2-month 15-minute data sets
  - Plot shear and combined velocity (u+v) spectra
  - Buoyancy frequency
  - Sync GitHub
  - Critical latitude/resonance
  - Tidal constituents
  - Critical slope angles
  - LaTeX/bibdesk

1.8 January 6th, 2020

- **Work**:
  - Directed reading
  - Readings club
  - Sync GitHub
  - Tidal constituents
  - Improved filter
  - Noise averaging, smaller y-range, frequencies, comparative spectra, dates
- **To do:**
  - GM Toolbox > Buoyancy frequency
  - Shear spectra (du/dz)
  - Rotary Spectra > spectrogram
  - Critical latitude / resonance
  - Wind data (Ed/Tofino)
  - Haley waves textbook
  - Rotate velocity profiles $\tilde{u} = u + iv \rightarrow u_{\text{new}} = \tilde{u}e^{i\theta}$
  - Process to loop through data/plot (glob and xarray.open_mfdatasheet)
  - Improve code
  - LaTeX/BibDesk

1.9 January 28th, 2020

- **Work**:
  - Check available data (see notes)

- Parzen window for wider binning, nperseg to 400 for averaging (smaller window size for high frequency)
  - Tidal constituents
  - Improved plots
- **To do**:
  - Buoyancy frequency (GC La Perouse)
  - GM Toolbox
  - Shear (du/dz), rotary, spectrogram, crit. lat., resonance, slope angle
  - Process/script/improve code (see Jan. 6)
  - Rotate spectra
  - Wind (Ed/Tofino)
  - Error bars, units, reorganise comparisons, comments

1.10 February 25th, 2020

- **Work**:
  - Interpretations of spectra (see notes)
- **To do**:
  - Winter vs summer plots + axis + annual + plot over each other
  - Summer climatology, year matters
  - GM spectra > WKB scaling
  - More comments
  - Smaller window size for high freq. > better averaging
  - 15-min 2-month data sets
  - Process to generate plots / improve code (see earlier notes)
  - Shear, rotary, crit lat and resonance, slope angle, wind, spectrogram
  - LaTeX / BibDesk
  - Haley waves textbook
- **Meeting notes:**
  - Plot total velocity $u^2 + v^2$
  - Plot -2 slope line until GM
  - Plot N^2 for summer + winter; WKB scaling for N
  - Plot average 2018 vs winter & summer; Plot average of earliest year vs 2018
  - Rotate for slope angle (u,v > complex > e^{itheta} > Re, Im > new u,v)
  - Depth mean spectra vs baroclinic
  - Compare with papers, offer more interpretation
  - **SEND PLOTS EARLIER**

1.11 March 1st, 2020

- **To do**:
  - Winter vs summer / annual (*same Notebook*) / spectra overlaid
  - Upper slope vs axis (15 min / 2 month)
  - Climatology for summer / annually, then plot $N^2$for winter and summer (WKB?)
  - GM (see earlier notes)
  - Comments, interpretation, and captions in a new LaTeX document
  - Better averaging for high frequency PSD (see earlier notes)
  - Shear/rotary/crit lat and resonance/slope angles+scat+refl/wind(Ed/Tofino/ONC)/Spectro
  - BibDesk / Haley waves textbook / Readings
- **Priority from meeting**:
  - -2 slope line for PSD until GM
  - Adjust for slope angle (see earlier notes)
  - Compare with nearby papers w/ similar conditions

– Plot average 2018 vs winter/summer 2018 and earliest year possible
– Depth mean spectra vs individual depths
– **Send plots earlier!** LaTeX document to keep up
– Check for backwards depths
– Compile code
– Deviation spectrum u –u
– Fit continuum slope Ae^k vs Be^k

1.12 March 16th, 2020

- **Priorities**:
  - LaTeX doc + **send plots earlier**
  - Better averaging (see earlier notes)
  - Rotate spectra (see earlier notes)
  - Compare w/ other papers
  - Plot N^2 for summer/winter through depth: climatology for summer + annually > WKB scaling > plot GM spectra instead of -2 line
  - Plot avg. annual behind summer/winter, and vs other years (earliest/all)
  - Plot deviation spectrum $u - \overline{u}$
  - Plot fits for continuum slope Ae^k vs Be^k
- **To do:**
  - Compile/optimise code > auto-generate all plots from 15-min 2-month data sets
  - Shear (du/dz) / rotary (see earlier notes) / crit. lat. + resonance / slope angle + scat. + refl. / wind (Ed/ONC) / Spectrogram
  - Switch to BibDesk (after getting LaTeX going)
  - Haley's waves textbook
  - Continue reading
- **Meeting notes**:
  - Meetings changed to Tuesday, and digital due to COVID-19 constraints.
  - Classes cancelled until further notice, though assignments/projects are still due.
  - Resolve LaTeX issues, and send to Jody.
  - Check when grades are due, to potentially delay PHYS 580 project.

1.13 March 24th, 2020

- **Completed**:
  - Fix LaTeX issues and send document to Jody.
  - Convert from Mendeley to Bibdesk to use with LaTeX.
  - Preliminary rotation of velocities (test 30°angle). Rotation direction confirmed (requires $e^{-i\theta}$)
  - Better averaging for visual clarity of spectral peaks.
  - Check when grades are due, to potentially delay PHYS 580 project. Jennie says one week after the end of the exam period (see email, forwarded info to Jody).
- **Priorities**:
  - Finish adding plots and captions to LaTeX document
  - Determine proper angle to rotate spectra
  - Compare w/ other papers in region (Mihaly ∼300km away and >1000m deeper, only somewhat useful for comparison, aka should be very different)
  - Plot avg. annual behind summer/winter, and vs other years (earliest/all)
  - Plot deviation spectrum $u - \overline{u}$
  - Plot fits for continum slope Ae^k vs Be^k
  - Plot N^2 for summer/winter through depth: climatology for summer + annually > WKB scaling > plot GM spectra instead of -2 line
- **To do:**

- Compile/optimise code > auto-generate all plots from 15-min 2-month data sets
  - Shear (du/dz) / rotary (see earlier notes) / crit. lat. + resonance / slope angle + scat. + refl. / wind (Ed/ONC) / Spectrogram
  - Haley's waves textbook
  - Continue reading
- **Meeting notes**:
  - Finish LaTeX doc (add missing winter plots/Axis)
  - Rename u and v to cross-slope and along-slope velocities, respectively
  - Look for Mihaly's A1 site for comparison data
  - Prioritise annual spectra (seasonal vs, yearly vs, decadal)
  - Committee? Jody Klymak; Steve Mihaly; Richard Dewey; Rick Thomson; Johannes Gemmrich

1.14 April 2nd, 2020

- **Completed**:
  - Check when grades are due, to potentially delay PHYS 580 project. Recent email says May 15.
  - Did Jody receive Assignment #11 for PHYS 580?
  - Plotted rotated velocities and spectra, with captions, for Upper Slope summer 2018.
  - Better averaging for visual clarity of spectral peaks (can leave this alone for now).
  - Optimised code for producing rotated plots (still not automated).
  - Rename u and v to cross-slope and along-slope velocities, respectively, for all rotated instances.
  - Finished adding descriptive captions to all plots already present in document.
- **To do (priority)**:
  - Finish adding Upper Slope winter and Axis plots with captions to LaTeX document.
  - Plot avg. annual vs seasonal, annual, and decadal
  - Compare w/ other papers in region, look for Mihaly A1 site research
  - Plot deviation spectrum $u - \overline{u}$
  - Plot fits for continum slope Ae^k vs Be^k
  - Plot N^2 for summer/winter through depth: climatology for summer + annually > WKB scaling > plot GM spectra instead of -2 line
- **To do:**
  - Compile/optimise code > auto-generate all plots from 15-min 2-month data sets
  - Shear (du/dz) / rotary (see earlier notes) / crit. lat. + resonance / slope angle + scat. + refl. / wind (Ed/ONC) / Spectrogram
  - Committee? Jody Klymak; Steve Mihaly; Richard Dewey; Rick Thomson; Johannes Gemmrich
  - Haley's waves textbook
  - Continue reading
- **Meeting notes**:
  - Continue with priority list.
  - Can take chair from school for back.
  - Don't need to make code too fancy, just easy to use.
  - Can average time series in smaller chunks (2-month) and then combine for annual averages, etc.

1.15 April 7th, 2020

- **Completed**:
  - Improved plots to be more comparative and reduce sheer number of individual figures.
  - Finished adding rotated Upper Slope winter 2018 plots (with captions) to LaTeX document.
  - Added interpretation section to end of document to provide a running summary of captioned descriptions.
  - Added 2018 annual plot, but it's incorrect (see priority list, below).
  - Fixed code to call specific depth and time ranges for any input dataset, to work with 15-minute interval data (filters and FFT) versus previous hourly, and to merge datasets when necessary.

Much better!

- **To do (priority)**:
  - Focus on finishing the term.
  - Committee members and meeting? Jody Klymak; Steve Mihaly; Richard Dewey; Rick Thomson; Johannes Gemmrich
  - Replot Upper Slope w/ 15-minute resolution data for 2018.
  - Plot avg. annual vs seasonal, annual, and decadal (2-month and combine for annual averages).
  - Plot Axis ADCP data versus Upper Slope
  - Compare w/ other papers in region (look for Mihaly A1 site research). Need to begin telling story.
  - Plot deviation spectrum $u - \overline{u}$
  - Plot fits for continum slope Ae^k vs Be^k
  - Plot N^2 for summer/winter through depth: climatology for summer + annually > WKB scaling > plot GM spectra instead of -2 line
- **To do:**
  - Shear (du/dz) / rotary (see earlier notes) / crit. lat. + resonance / slope angle + scat. + refl. / wind (Ed/ONC) / Spectrogram
  - Analyse residual data
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
  - Continue reading
- **Meeting notes**:
  - Email Rick Thomson, cc. Jody and Steve. Description of work, maybe show a spectra (winter vs summer?) and description.
  - Instead of worrying about velocities, get a matrix of spectra that can be saved to netCDF. e.g. for each two-month slice compute the spectra and save the amplitude for each frequency bin, compile. That way all spectra have same resolution/binning/etc.

1.16 June 16th, 2020

- **Completed**:
  - Updated thesis schedule to better reflect committee meeting discussion and presentation slides.
  - Improved commenting on in-progress spectra matrix code, and reorganised/improved formatting of code.
  - Improved velocity plots to be more comparative, and corrected date range issues for velocity data (but now there is a strange line, need to check all the winter 2018 plots for date range issues; there is the same issue with w, for sure).
  - Contacted Steve regarding the cruise he mentioned during the committee meeting.
  - Began adjusting committee meeting outline to become the official Project Proposal. Ask Jody about what to keep and what to add.
  - Merged all the data for Upper Slope 75 kHz ADCP. Working on Axis.
  - Replotted Upper Slope w/ 15-minute resolution data for 2018, to check code working as it should. Winter has date range issues.
  - Quick re-read of some earlier papers to try and understand them better (Mihaly and Thomson; Garrett and Munk, etc.). Need to read again to summarise methods and come up with questions.
- **To do (priority)**:
  - Ask Jody about the Fluids grade that still doesn't show up on the UVic site.
  - Finish matrix code, and better document code (technical appendix).
  - Read, and document potential methods (below) and questions for Jody.
  - Work on Project Proposal.
- **To do:**
  - Fix date range issues with Slope winter 2018 plots.
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).

- Haley's waves textbook
- Continue reading and evaluate papers for potential research methods. Ask Jody questions. Code and document code. Work on Project Proposal.

- **Meeting notes**:
  - Meetings to be held Tuesdays at 11am.
  - Split time between coding, documenting code, reading and evaluating papers, and working on project outline.
  - Matrix is only a tool for analysis. If not working well, use simpler methods.
  - For next time, have some reading notes, proposal outline, and analysis prepared.
  - Matrix should be for every depth (3D matrix).
  - Ask Jennie about grades.

1.17 June 23rd, 2020

- **Completed**:
  - Confirmed Fluid grade with Jennie.
  - Heard from Steve regarding the Akash cruise he mentioned, waiting to hear back with more information.
  - Adjusted meeting outline to serve as an outline for the project proposal.
  - Comparative velocity data for Upper Slope in 2012 to Thomson plots to visually check coherence, to reference for current information moving forward.
  - Reading of three papers (see below), summarising results and useful methods (updated). Questions to be asked.
- **To do (priority)**:
  - Finish matrix code, aside (3D, through depth), and better document code (technical appendix).
  - Read, and document potential methods (below) and questions for Jody.
  - Work on Project Proposal.
- **To do:**
  - Add fM_2 and M_4 lines to spectra. See reading notes.
  - Fix date range issues with Slope winter 2018.
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
- **Meeting notes**:
  - Look for two-week pulses in velocity data / spectrograms.
  - Check Rick's book for general oceanographic concepts.
  - Check Alford articles for information on rotary spectra.
  - Create a spectrogram for along-slope velocity data, using a log scale for frequency, a specific depth, and a time scale that are all relevant. Scale frequencies and velocities to try and show something.

1.18 July 14th, 2020

- **Completed**:
  - Created a spectrogram for along-slope velocity data, for 2018 to compare with previous seasonal data. Still trying to find a paper with a spectrogram to compare with. Difficult to interpret; may need adjustments as suggested by Jody.
  - Updated schedule with an annual PSD for 2018, including fM_2 and M_4 frequencies, as from Mihaly and Thomson. This could indicate non-linear wave-wave interaction as a means of energy decay for internal waves, due to downward wind internal waves and upward topographic internal tides. There should be winter intensification. Look into their relative energy (versus total). Rotary spectra useful for analysis. Can compare to this paper, though they look at a greater depth (2000 m) and distant site (250 km).
  - Reading (see below), summarising results, useful methods (updated), and questions to be asked.

- Updated plots and analysis in this document as relevant to readings.
- **To do (priority)**:
  - Improve spectrograms.
  - Read, and document potential methods (below) and questions for Jody.
  - Work on Project Proposal.
  - Document code for a technical appendix.
- **To do:**
  - Fix date range issues with Slope winter 2018.
  - Finish matrix code as an aside (3D, through depth).
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
- **Meeting notes**:
  - Add depth to spectrogram.
  - Captions updated to be more descriptive (depth, mean-removed, etc.).
  - Show all data, can zoom in later.
  - Save Sxx and other matrices for later use, rather than calculating each time.
  - log10 the Sxx for better visual clarity, and multiply by frequency-squared to 'whiten'.
  - Show examples of work if stuck.
  - 2D spectra (time/depth) as To Do (Priority) analysis.
  - For internal waves, both cross- and along-slope are important.
  - N**2 climatology through depth, for summer and winter, annually ¿ WKB scaling ¿ GM spectrum as To Do (Priority) analysis.
  - Rotary spectra for To Do (Priority) analysis.
  - Seasonal wind forcing as To Do (Priority) analysis.
  - Research 'σ-t surface'

1.19 July 21st, 2020

- **Completed**:
  - Updated a spectrogram for along-slope velocity data, for 2018 to compare with previous seasonal data as a sample. Added specific depth to plot, removed y-axis limits, updated caption, set color normalisation to log10, and 'whitened' (multiplied Sxx by frequency**2). Still trying to find a paper with a spectrogram to compare with. Next, create one for each year to look for trends.
  - Obtained and formatted climatology data from Line P cruises (DFO) for winter and summer of 2009 - present.
  - Wrote code to calculate density (UNESCO 1983) and buoyancy frequency (N^2) through depth, for winter and summer, annually. What is the best depth range to use for finding dρ/dz? Should all plots have the same frequency scale, regardless of the shallow spike? Plots sent in email. Next steps are WKB scaling and then using a GM toolbox for the spectrum.
  - Began rotary spectral analysis. Not complete, as the FFT of the vector form of the horizontal velocity is giving me NaN values.
  - Reading (see below), summarising results, useful methods (updated), and questions to be asked.
  - Updated plots and analysis in this document as relevant to readings.
- **To do (priority)**:
  - Spectrograms annually, for both cross- and along-shore velocities.
  - WKB scaling for buoyancy and velocity (Alford) > plot GM spectra instead of -2 line (Alford).
  - Rotary spectra (Alford/Mihaly).
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and canyon upwelling (Allen).
  - 2D spectra (time/depth).
  - Read, and document potential methods (below) and questions for Jody.

- Work on Project Proposal.
- Document code for a technical appendix.

- **To do:**
  - Finish matrix code for spectra as an aside (3D, through depth).
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
- **Meeting notes**:
  - N seems high (6e-3 Hz). Use 'Seawater' toolbox for EoS calculations, compare to my results.
  - Split N2 plots into shallow and deep. Share axes. No WKB stretch necessary, as N doesn't change much below 100m.
  - Plot density profiles
  - Do not label conductivity (C) as salinity (S), or vice versa.
  - No need of for loops if a variable is vectorised.
  - Move legend off of spectrogram plots, remove smoothing, save as PDF. Annual plots, zoom in on notable events, determine timescale of events similar to storms (compare with wind data).
  - Rotary spectra can use a scipi PSD routine (probably not Welch).

1.20 July 28th, 2020

- **Completed**:
  - This week some extra TA duties were necessary to complete, as the course is now over.
  - Writing of some award statements for UVic graduate awards.
  - Moved legend to the side of spectrogram plots. Removed smoothing. Changed save format to rasterised PDF. Began creation of rough annual plots, but these need to be checked vs data gaps to ensure proper coverage. Figure this out then plot the annual spectrograms for Axis ADCP.
  - There is an issue with depth. As time progresses the depth data becomes changes in resolution, and this is causing issues with my code to automatically create the spectrogram each year. Working on creating each annual plot manually, while I figure it out.
  - Shifted analysis to end of document, for better organisation.
  - No reading this week.
- **To do (priority)**:
  - Update plots in thesis schedule document.
  - Annual plots, zoom in on notable events, determine timescale of events similar to storms (compare with wind data). Both cross- and along-shore data.
  - N seems high (6e-3 Hz). Use 'Seawater' toolbox for EoS calculations, compare to my results. Split N2 plots into shallow and deep. Share axes. No WKB stretch necessary, as N doesn't change much below 100m. Plot density profiles. Do not label conductivity (C) as salinity (S), or vice versa.
  - Use N^2 data to plot GM spectra instead of -2 line (Alford).
  - Rotary spectra (Alford/Mihaly). Use a scipy PSD routine (not Welch).
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and canyon upwelling (Allen). Also to compare to intervals of internal wave activity visible in spectrograms.
  - 2D spectra (time/depth).
  - Repeat for Axis data.
  - Read, and document potential methods (below) and questions for Jody.
  - Work on Project Proposal.
  - Document code for a technical appendix.
- **To do:**
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
- **Meeting notes**:

- Continue with last week's methods.
- For the depth issue, either a) homogenise the datasets, b) remap to a single depth scale, or c) pick a specific depth and interpolate onto it, when necessary. (c) is probably the best option.
- Update Jody next Thursday or Friday, as he is away until the 12th.
- Schedule a meeting for after the 12th, closer to the date.

1.21 August 25th, 2020

- **Completed**:
  - Further optimised code for automating plots of N^2, spectrogram, PSD, and velocity, for both ADCP.
  - Linearly interpolated for missing depth values, as depth resolution improved over the total duration of the dataset. Checked vs ONC data output and data gaps are in the appropriate places; nothing (or very little) seems to be missing. Will add the 55 kHz Axis ADCP to fill some data gaps.
  - Remade spectrogram plots for all years, and both Upper Slope and Axis ADCP, using the interpolated depth data. Moved legend to the side. Removed smoothing. Updated save format to rasterised PDF, and also automated the titles and filename for each plot that is generated. Plots available in the spectro_plots folder on GitHub.
  - Remade velocity plots for all years, both Upper Slope and Axis ADCP. Plots available in the vel_plots folder on GitHub.
  - Used Seawater package for more accurate calculations. Split N^2 plots into shallow (¿-200 m) and deep (¿-200 m). Plotted density, temperature, and salinity profiles alongside. Shared axes for comparison between seasons, years, and the shallow/deep split. No WKB stretch necessary, as N doesn't change much at all below 100 m. Changed label of salinity from (C) to (S). Plots available in the N2_plots folder on GitHub.
  - Finished adapting a Python package for the GM81 spectrum. Added the GM spectrum to annual spectra, but not yet to the monthly/seasonal spectra.
  - Nearly have rotary spectra working. Using Rick's book as a guide for the FFT process.
  - Compiling of required documents for graduate awards.
  - Shifted reading notes to end of document, for better organisation. See this new section for details of weekly readings, if interested, and I'll bring up relevant questions when necessary.
  - General update to brief interpretation section, reflecting improved insight over time.
  - Two papers reviewed, among others read; see 'Relevant reading' section at the end of this document.
- Updated brief analysis section, below.
- **To do (priority)**:
  - Update schedule document with plots.
  - Zoom in on notable events, determine timescale of events similar to storms (compare with wind data). Comparison of Axis and Upper Slope plots.
  - Get data from additional Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years.
  - Redo monthly/seasonal spectra with GM line, and annual to fix vline colours.
  - Redo spectrograms with borderless legend.
  - Finish rotary spectra (Alford/Mihaly). Use a scipy PSD routine (not Welch).
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and canyon upwelling (Allen). Also to compare to intervals of internal wave activity visible in spectrograms.
  - 2D spectra (time/depth).
  - Read, and document potential methods (below) and questions for Jody.
  - Work on Project Proposal.
  - Document code for a technical appendix.

- **To do:**
  - Inquire with Steve regarding the unreliable Mid-East ADCP data (could be useful if fixed).
  - Haley's waves textbook
- **Meeting notes**:
  - GM spectrum should go to infinite at f. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation).
  - For rotary spectra, try making a fake circular dataset to practice on, to see if things are working properly.
  - Show 'odd spikes' in spectra in the velocity data (zoom in to the period in question for that frequency).
  - Where the PSD 'flattens out' there could be the 'noise floor' of the ADCP. Get the specs and plot that line.
  - Plot comparative data between years and ADCP.
  - Spectrograms at upper and lower depths for both ADCP. Profile vs depth of high frequency energy vs depth to show strength of these peaks/seasonality at different depths.
  - Spectrogram units are off (it's whitened). Be careful of units, always.
  - New analysis document. Summarise with plots, point form or paragraph for each point of analysis.
  - Thesis proposal (why, importance, what's been done/lit review, is it an advance?), etc.

1.22 September 17th, 2020

- **Completed**:
  - Primarily writing and developing plots for a Preliminary Analysis document to record potential findings. Also moved and updated any relevant information from this document to there.
  - Created an outline for the first few sections of my Thesis document, including a start on writing the introduction and methods sections. Needs plenty of work.
  - 6 more papers reviewed (most within the past 10-15 years), among others skimmed; see 'Relevant reading' section at the end of this document for details.
  - Courses (Thursday evenings) and TA work (Friday afternoons) began again, last week. These should only require about two days a week, total.
  - Coding on pause recently to catch up on reading and writing. Primarily need to finish rotary spectra, among other things. Using Rick's book as a guide for the FFT process, and Jody's suggestion of a sample dataset.
  - Revised code for optimised output of desired figures (mainly how figure titles are automated to suit any customisation I want from a plot).
- **To do**:
  - New analysis document. Summarise with plots, point form or paragraph for each point of analysis.
  - Thesis proposal (why, importance, what's been done/lit review, is it an advance?), etc.
  - Finish rotary spectra (Alford/Mihaly). Use a scipy PSD routine (not Welch). For rotary spectra, try making a fake circular dataset to practice on, to see if things are working properly.
  - GM spectrum should go to infinite at f. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Add to all spectra.
  - Spectrogram units are off (it's whitened). Need to fix. Be careful of units, always.
  - Zoom in on notable events, determine timescale of events similar to storms (compare with wind data). Comparison of Axis and Upper Slope plots.
  - Show 'odd spikes' in spectra in the velocity data (zoom in to the period in question for that frequency).
  - Get data from additional Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East ADCP data, as it could be useful for a three-way comparison.

- Where the PSD 'flattens out' there could be the 'noise floor' of the ADCP. Get the specs and plot that line.
- Plot comparative data between years, seasons, annual seasons, and ADCP. Spectrograms at upper and lower depths for both ADCP. Profile vs depth of high frequency energy vs depth to show strength of these peaks/seasonality at different depths.
- Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and canyon upwelling (Allen). Also to compare to intervals of internal wave activity visible in spectrograms.
- 2D spectra (time/depth).
- Read, and document potential methods (below) and questions for Jody.
- Document code for a technical appendix.

• **Meeting notes**:
  - Add importance and personal opinion to reading notes.
  - Create a draft proposal/outline, with the finished product to be ready by mid-October, and a draft in three weeks. Can send Jody drafts whenever, for feedback.
  - For next week, finish/continue the Analysis document, send proposal outline with goals and relevant papers (a day early), and share a notebook with a test case of rotary spectra.

1.23 September 24th, 2020

• **Completed**:
  - Continued to expand the Proposal document introduction and methods sections. Added project goals (research questions). Updated relevant reading/references.
  - For the Analysis document, completed plots and analysis for two sections, Axis 75 kHz ADCP, and N^2 and CTD data. Added outlines for Axis 55 kHz ADCP and 'Upper Slope vs Axis' sections, to come next.
  - Used Rick's book and his source Gonella (1972), as well as some in-progress code from GitHub, as a guide to develop an example rotary spectra case. I'm still doubtful it's working correctly, but I think I have it lined up with the math, as described. Sent via Jupyter Notebook file to Jody.
  - Adjusted spectrogram and N^2 units.
  - Revised N^2 and CTD plots for comparative scales.
  - Two papers reviewed, relevant to rotary spectra; see 'Relevant notes' section at the end of this document for details.
  - Added 'Importance' and 'Personal opinion' to reading reviews.
  - Courses (Thursdays) and TA work (Fridays), as usual. As expected, 2-3 days of work each week.

• **To do**:
  - Finish thesis Proposal document (why, importance, what's been done/lit review, is it an advance?) by mid-October. Be specific for 2-3 project goals. Expand with more of a roadmap. Others are optional, but possible.
  - Finish rotary spectra (Thomson, Gonella). Perhaps send test case to Rick to see what he thinks?
  - Get data from additional Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East ADCP data, as it could be useful for a three-way comparison.
  - Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable, between instruments.
  - GM spectrum is wrong, it should go to infinite at f. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all spectra.
  - Identify ADCP noise floor to indicate on PSD.
  - Plot the profile through depth of high frequency energy vs depth to show strength of these peaks/seasonality at different depths.
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-

inertial internal waves that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
  - 2D rotary spectra (time/depth), see Pinkel.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Proposal. Be specific for 2-3 project goals. Expand with more of a roadmap. Others are optional, but possible.
  - Rotary. Add some noise. Frequency output is 'positive definite', so CCW for a CW spectrum still shows up (maybe it's actually negative). Use more data points, more ω, longer period. Throw out half of the spectrum since only half of the frequencies are real, then double the amplitude. Maybe add a tide going in mostly one direction. See Pinkel for 2D rotary spectra examples.
  - For deep flow in and upper flow out of the canyon, check velocity rotation.
  - Continue with Analysis additions.

1.24 October 5th, 2020

- **Completed**:
  - For the Proposal document, expanded each of the proposed primary research goals to be descriptive of the process to be followed, more of a roadmap. Expanded the relevance of each method of analysis to the proposed research goals. Expanded methodology for each form of analysis, and added 2D and rotary spectra descriptions. Ideally, a mostly complete rough draft could be delivered for critique by the end of the week, or next meeting.
  - Finished rotary spectra test case. Added more data points, higher ω, and a longer period to better interpret the results of the test case code. Added some noise, and M2 tide in mostly the u direction. Threw out half of the spectrum since only half of it is real, and doubled the amplitude. Spectra appear to be as expected.
  - For the Analysis document, rotary spectra plots are being made. The 55 kHz data is still being plotted, once rotary plots for the other two ADCP are finished.
  - Obtained updated data from ONC for the 55 kHz ADCP (see above), along with data for the Mid-West and Mid-East ADCP for potential comparison in cases where Upper Slope and Axis are not overlapping. Formatted data for analysis (convert to NetCDF, combining data sets, and some interpolation to deal with data gaps and NaN values in time and depth).
  - One chapter reviewed; see 'Reading notes' section at the end of this document for details.
  - Courses (Thursdays) and TA work (Fridays), as usual. As expected, 2-3 days of work each week. Course is proving to be very difficult, and the assignments are time consuming.
- **To do**:
  - Finish thesis Proposal document Introduction (why, importance, what's been done/lit review, is it an advance?) with examples of analysis, by mid-October.
  - Update Analysis document with rotary spectra plots. See Pinkel for 2D rotary spectra examples, time/depth.
  - Convert and plot Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East and Mid-West ADCP data, as it could be useful for a three-way comparison. Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable between instruments.
  - GM spectrum is wrong, it should go to infinite at f. Careful of one-sided amplitudes. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all spectra.
  - For deep flow in and upper flow out of the canyon, check velocity rotation.

- Cross-section of local bathymetry.
- Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
- Document code for a technical appendix.
- Read more!

- **Meeting notes**:
  - 1D rotary spectra to start. Then 2D, as finding an optimal window will be difficult.
  - Approach other students, and past students, for support in PHYS 502.
  - Proposal edits, rotary spectra, and finish some items on checklist for next week.

1.25 October 8th, 2020

- **Completed**:
  - Continue editing Proposal.
- **To do**:
  - Finish thesis Proposal document Introduction (why, importance, what's been done/lit review, is it an advance?) with examples of analysis, by mid-October.
  - Update Analysis document with rotary spectra plots. See Pinkel for 2D rotary spectra examples, time/depth.
  - Convert and plot Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East and Mid-West ADCP data, as it could be useful for a three-way comparison. Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable between instruments.
  - GM spectrum is wrong, it should go to infinite at f. Careful of one-sided amplitudes. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all spectra.
  - For deep flow in and upper flow out of the canyon, check velocity rotation.
  - Cross-section of local bathymetry.
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Continue as previous meeting.

1.26 October 15th, 2020

- **Completed**:
  - Continue with Proposal edits. Finished thesis Proposal document Introduction (why, importance, what's been done/lit review, is it an advance?) with examples of analysis.
- **To do**:
  - Finish final edits of Proposal.
  - Update Analysis document with rotary spectra plots. 1D, then see Pinkel for 2D rotary spectra examples, time/depth.
  - GM spectrum is wrong, it should go to infinite at f. Careful of one-sided amplitudes. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all

spectra.
- Convert and plot Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East and Mid-West ADCP data, as it could be useful for a three-way comparison. Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable between instruments.
- For deep flow in and upper flow out of the canyon, check velocity rotation.
- Cross-section of local bathymetry.
- Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
- Document code for a technical appendix.
- Read more!

- **Meeting notes**:
  - Focus on importance, remove fluff, essay style with argument, and what's new.
  - Continuum is very important, for confirming seasonal changes related to wave-wave interaction, breaking, etc. Read Alford's student's paper again for more details. Needs to be more of a focus.
  - Send final draft of Proposal to Jody by early next week.

1.27 October 22nd, 2020

- **Completed**:
  - Final edits of Proposal document.
  - Continue to check out rotary averaging.
- **To do**:
  - Update Analysis document with rotary spectra plots. 1D, then see Pinkel for 2D rotary spectra examples, time/depth.
  - GM spectrum is wrong, it should go to infinite at f. Careful of one-sided amplitudes. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all spectra.
  - Convert and plot Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East and Mid-West ADCP data, as it could be useful for a three-way comparison. Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable between instruments.
  - For deep flow in and upper flow out of the canyon, check velocity rotation.
  - Cross-section of local bathymetry.
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Final edits by early next week. Get to work on To Do list to catch up.

1.28 October 29th, 2020

- **Completed**:
  - Final draft of Proposal document sent to Jody. After review will send to Steve and Rick for feedback.

- Finally figured out averaging for rotary spectra using CSD/PSD functions in SciPy, and it works! Normalisation also checks out. See rotary_test.ipynb for details. Test case for Upper Slope 2013 looks good as compared to papers such as Mihaly 1997. See the Rotary section in analysis.ipynb for details.
  - Working on fixing issues with locally calibrated GM spectrum.
  - Reading focused on rotary spectra interpretation and continuum analysis. See 'Reading notes' section for details.
- **To do**:
  - Update Analysis document with rotary spectra plots. 1D, then see Pinkel for 2D rotary spectra examples, time/depth.
  - GM spectrum is wrong, it should go to infinite at f. Careful of one-sided amplitudes. f should be in radians in input code. Careful of K and P energy vs total energy when getting GM spectrum. N^2 shouldn't be Hz^2, it should probably be $[rad/s]^2$ (see GM documentation). Adjust in all spectra.
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
  - Continuum is very important for confirming seasonal changes related to wave-wave interaction, breaking, etc. Read Alford's student's paper again for more details. Needs to be more of a focus.
  - For deep flow in and upper flow out of the canyon, check velocity rotation.
  - Cross-section of local bathymetry.
  - Seasonal wind forcing (Ed/ONC/NOAA/NARR or buoy 46206 (Allen)) for downward near-inertial internal waves and inertial currents (rotary) that may affect deep ocean mixing (Alford/Allen), and equatorward current that force canyon upwelling (Allen). Also for simple comparison to intervals of high frequency activity visible in spectrograms.
  - Convert and plot Axis 55kHz ADCP to fill some data gaps and resolve issues with Axis 75 kHz in later years. Inquire with Steve regarding unreliable Mid-East and Mid-West ADCP data, as it could be useful for a three-way comparison. Update Analysis document with Axis 55 kHz and cross-instrument comparison sections. Fix PSD axes so that they're the same and comparable between instruments.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Begin using GitHub project manager for To Do list. Link docs on GitHub.
  - Finish Proposal when Jody gives final edits.
  - Finish with rotary spectra for other years. PSD still important for baseline comparisons. Why is M2 greater in CW than CCW? Find consistency relations. Spectrograms for rotary spectra. Check Gill, and Klymak 2015. Is there a GM rotary spectrum?

1.29 November 5th, 2020

- **Completed**:
  - GitHub now primary tool for tracking project. Added a readme, and linked all docs.
  - Final draft of Proposal document sent to Jody. After review will send to Steve and Rick for feedback.
  - GM spectrum up and running between f and N, but has too much energy by comparison.
  - Reading focused on GM and buoyancy relationship. See 'Reading notes' section for details.
  - Midterm + TA, as usual.
- **To do**:
  - Update docs and GitHub, regularly.
  - GM spectrum is wrong, has too much energy. Check vs other papers to see if process works OK.
  - Rotary spectra (1D and 2D).
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
  - Continuum evaluation.

  - Deep flow in and upper flow out of the canyon.
  - Local bathymetry.
  - Characterise seasonality.
  - Check Axis 55 kHz data.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Check GM vs other papers. If wrong, let the package creator know. Check vs Jody package.

1.30 November 19th, 2020

- **Completed**:
  - Proposal approved and sent to Rick and Steve for review.
  - GM spectrum more appropriate, but not sure why (just redid it the same as before). Should compare to papers again and show Jody proof that it's working correctly.
  - Created coarse local bathymetry map. Jody will provide high-res data.
  - Rotation for velocities double-checked, looks good.
  - Reading focused on GM process. See 'Reading notes' section for details.
  - Class + TA, as usual.
- **To do**:
  - Update docs and GitHub, regularly.
  - GM spectrum is working, but need to prove it.
  - Rotary spectra (1D and 2D).
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
  - Continuum evaluation.
  - Deep flow in and upper flow out of the canyon.
  - Create high-res local bathymetry map.
  - Characterise seasonality.
  - Check Axis 55 kHz data to fill data gaps.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Plot potential density, not density. Different scales for upper and lower depths. Use specific depth for GM process.
  - Why is my new GM process correct? Prove vs papers, show parameters. Find mistake.
  - Keep up with flow in flow out event for Axis.
  - Get better GEBCO data from Jody.
  - Kunze and Gregg for rotary GM.

1.31 November 26th, 2020

- **Completed**:
  - Confirmed GM spectrum by comparing with Alford 2012, but can't find my mistake (checkpoints don't work).
  - Checking Cairns & Williams for rotary GM process.
  - Replotted buoyancy and CTD data with appropriate scales and potential density.
  - Reading focused on fixing GM process. See 'Reading notes' section for details.
  - Class + TA, as usual.
- **To do**:
  - Update docs and GitHub, regularly.
  - GM spectrum is working, but need to prove it.
  - Rotary spectra (1D and 2D).
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.

- Continuum evaluation.
- Deep flow in and upper flow out of the canyon.
- Create high-res local bathymetry map.
- Characterise seasonality.
- Check Axis 55 kHz data to fill data gaps.
- Document code for a technical appendix.
- Read more!

• **Meeting notes**:
- Improve bathymetry using Jody's high-res data.
- Add Notebook extension to Jupyter.
- Mention jklymak in GitHub for updates.
- Plot θ and not T.
- No sidereal days.
- For GM, use the KE spectrum only. Alford GM not explicit enough with parameters (WKB stretch? Divide by 4?).
- Check Jody's posted articles for rotary GM spectra details, and check references.
- Do some more reading on canyon inflow and outflow, and spring-neap effects (to indicate mixing as a driver).

1.32 December 4th, 2020

• **Completed**:
- Better confirmation of GM spectrum accuracy.
- Replotted bathymetry with higher resolution data.
- Replotted potential temperature instead of temperature.
- Reading focused on canyon flows. See 'Reading notes' section for details.
- Class + TA, as usual.

• **To do**:
- Update docs and GitHub, regularly.
- GM spectrum is working, but need to prove it.
- Rotary spectra (1D and 2D), and rotary GM spectra.
- Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
- Continuum evaluation.
- Deep flow in and upper flow out of the canyon.
- Characterise seasonality.
- Check Axis 55 kHz data to fill data gaps.
- Document code for a technical appendix.
- Read more!

• **Meeting notes**:
- Add Rick and Steve's suggestions to doc and GItHub. Read over break, and develop a list of questions for them. Show Jody, first.
- Check Axis data for issues (see velocity plots for bad spots). Gaps? Instrument swaps?
- Keep interpolation to a few hours, maximum.
- SciPy to read matlab files for 55 kHz data, then convert to NetCDF using xarray.
- 1/2 GM for rotary and component PSDs.
- Consider WKB scaling when comparing GM spectra. Typically 5.2e-3 unless otherwise stated.

1.33 December 11th, 2020

• **Completed**:
- Readjusted GM process, and compared with both Chen 2019 and Alford 2012 and it matches!
- Levine and Polzin use different rotary GM processes. Compared, and consult with Jody.
- Reading focused on GM parameters and comparing my spectrum with published work. See

'Reading notes' section for details.
  - Requested Axis 55 kHz ADCP velocity data from ONC.
  - Optimising analysis code to better deal with data gaps.
  - Final exam Monday, and extra grading this week.
- **To do**:
  - Update docs and GitHub, regularly.
  - Rotary spectra (1D and 2D), and rotary GM spectra.
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
  - Continuum evaluation.
  - Deep flow in and upper flow out of the canyon.
  - Characterise seasonality.
  - Check Axis 55 kHz data to fill data gaps.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  - Request ONC Axis 55 kHz data, cc Steve.
  - Recheck rotary GM with other papers. Try squared, and maybe a factor of 1/(2omg^2) for proper units? Try (omg^2 + f^2).
  - Depth mean spectrum is a squared quantity, so it can be lower than the others.
  - Try GM process with vector arrays.

1.34 December 17th, 2020

- **Completed**:
  - Unsuccessful in finding additional papers to compare rotary GM spectra with. Literature seems to agree that the factors should be squared.
  - Requested Axis 55 kHz ADCP velocity data from ONC. Worked with them to figure out permissions issues to get NetCDF data.
  - Trying to optimise analysis code to better deal with data gaps, which occur due to instrument swaps/adjustments that slightly change depth values (horizontal banding).
  - Reading focused on GM parameters and comparing my spectrum with published work. As well, new tidal analysis by Alford. See 'Reading notes' section for details.
- **To do**:
  - Update docs and GitHub, regularly.
  - Rotary spectra (1D and 2D), and rotary GM spectra.
  - Filter barotropic tides from spectra to check for residual baroclinic (internal) tides.
  - Continuum evaluation.
  - Deep flow in and upper flow out of the canyon.
  - Characterise seasonality.
  - Check Axis 55 kHz data to fill data gaps.
  - Document code for a technical appendix.
  - Read more!
- **Meeting notes**:
  -

2 Additional analysis

A selection of additional analysis that could be useful, from readings.

- Compare w/ other papers, and compare analysis for relevance to this research.
- Identify ADCP noise floor to indicate on PSD.
- Create a plot of the profile through depth of high frequency energy vs depth to show strength of these peaks/seasonality at different depths.
- Update filter and rotation methods to match Thomson, for comparison.
- Plot deviation velocity $u - \overline{u}$, shear (du/dz), and total velocity (u+v).
- Crit. latitude + resonance effects
- Slope angle, scattering, and reflection
- Plot fits for continuum slope Ae^k vs Be^k
- Evaluate ADCP pressure time series for quality of data (depth variation) (Alford).
- Wavelet analysis for coherency between A1/wind and these sites (Thomson).
- Upslope mixing due to internal bores due to remotely generated incoming baroclinic tides (Martini).
- Analyse residual data

3 Reading notes

A selection of papers that are useful, or at least informative:

Gemmrich, J., & Klymak, J. M. (2015). Dissipation of internal wave energy generated on a critical slope. *Journal of Physical Oceanography* , *45* (9), 2221–2238. https://doi.org/10.1175/JPO-D-14-0236.1

- Summary: Uses models with varying parameters to attempt to better understand internal waves and tides interacting over 'critically' sloped topography, and how this affects local energy dissipation and mixing. A 'critical' slope matches the propagation angle of travelling internal waves. Vertical shear during incident upslope currents leads to stratification and a bore-like phenomenon, causing high dissipation rates near the bottom. The dissipation dependence can be likened to an oscillating wedge in a stationary fluid. The entire process can be parameterised by a power law, and is useful for describing the tidal dissipation of internal wave energy near shelf topography.
- Methods: a comparison of real-world data to model results, evaluation of **slope angle** and other topographical features, identification of **local parameters** (f , N, etc.).

Klymak, J. M., Alford, M. H., Pinkel, R., Lien, R. C., Yang, Y. J., & Tang, T. Y. (2011). The breaking and scattering of the internal tide on a continental slope. *Journal of Physical Oceanography* ,*41* (5), 926–945. https://doi.org/10.1175/2010JPO4500.1

- Summary: Barotropic conversion of energy over abrupt topography generates low-mode internal tides that radiate away, carrying incident energy with it, rather than through local dissipation effects. This energy eventually hits significant shelf topography, and depending on whether the slope is sub- or super-critical to the incident internal tides, will be scattered or reflected. This study looks at the internal tide generating Luzon region, and the interaction of resultant internal tides with the nearby continental slope, and finds that the results likely follow a linear model of reflection, as predicted, with about 1/3 incident energy being reflected in the first mode (highly dependent on the phase of incident modes 1 and 2). There is also significant local dissipation, and evidence that shelfs are eroded by incident tides until they reach critical slope. Therefore, dissipation near shelfs is likely, but for supercritical slopes reflection is also significant.
- Methods: estimating **energy budgets** and propagation, identifying areas of critical slope and determining energy of **reflection or scattering** , distinguishing local wave generation from incoming, temporal definitions for local tidal constituents, signal decomposition (remove vertical means, tidal filters), further decomposition into vertical modes, shoreward net energy fluxes, identifying local overturns/dissipation/non-linear shocks

Thomson, R. E., & Krassovski, M. V. (2015). Remote alongshore winds drive variability of the California Undercurrent off the British Columbia-Washington coast. Journal of Geophysical Research: Oceans

- Summary: Variability in the California Undercurrent is defined using ADCP data from the A1 and BP2 sites at a higher vertical resolution than previously possible, and wind-generated coastal-trapped waves are evaluated for their contributions to this variability. Other, previously unnoted currents, are also detailed.
- Methods: Velocity data from ADCP can be used to define seasonal and annual variations in mean currents at various depths, and compared to these findings. In particular, the A1 mooring site is near to Barkley Canyon (25 km), and at a similar depth (500 m), during similar years (Series 2). If similar, perhaps some of these findings can be associated with internal wave generation by currents over the shelf/canyon.
- Methods: Obtain similar wind data from NOAA instruments or NARR near Barkley Canyon, to compare with seasonal variability in currents and internal waves.
- Methods: Emulate filtering and rotation methods for better comparison and proven methodology.
- Methods: Wavelet analysis for coherence between wind/current data between A1 and Barkley Canyon.
- Read: 'Neptune effect'? Holloway (1992) "Representing topographic stress..."

- Question: Why do wind effects from farther away (down the US coast) affect the Vancouver Island currents more than local wind effects?
- Question: How do coastal-trapped waves play a role in this variability coherence?
- Question: How relevant is the Oceanic Nino Index to internal wave variability, generally?

Mihaly, S. F., Thomson, R. E., & Rabinovich, A. B. (1998). Evidence for nonlinear interaction between internal waves of inertial and semidiurnal frequency. Geophysical Research Letters, 25(8), 1205–1208. https://doi.org/10.1029/98GL00722

- Summary: To better understand large-scale energy decay in the internal wave band, non-linear wave-wave interaction is suggested between the f and M2 frequencies caused by downward inertial wind waves and upward topographic internal tides.
- Methods: Look into the fM2 and M4 frequencies, their relative energy (versus total), and seasonal (winter) intensification. Rotary spectra and spectrograms useful for analysis. Compare to these findings, albeit at a greater depth (2000 m) and distant (250 km).
- Read: D'Asaro (1995) "Upper-ocean inertial currents…"
- Read: Thomson (1990) "Near-inertial motions over…"
- Question: Why does a predominantly CW energy suggest the energy is in the form of a 'freely' propagating internal wave? Something to do with Coriolis?

Alford, M. H., Cronin, M. F., & Klymak, J. M. (2012). Annual cycle and depth penetration of wind-generated near-inertial internal waves at ocean station papa in the northeast pacific. Journal of Physical Oceanography

- Summary: Two years of ADCP velocity data were analysed at Ocean Station Papa in the Northeast Pacific, to better understand the role of downward penetrating near-inertial internal waves (>800 m) in mixing the deep ocean, as generated by passing storms at the surface. Some of the analysis is still beyond me, at this point.
- Methods: Compare regional wind data to the downward motion of near-inertial internal wave energy to compare to these findings, as moorings are at similar depths (<800 m) but in deep water and distant (1000 km). Evidence of propagation as downward and rightward swathes in the velocity profiles, following storms.
- Methods: Evaluate pressure to determine data quality of ADCP (depth variability).
- Methods: WKB scaling of buoyancy and velocity data through depth, to obtain proper estimates of energy, and apply GM theory. Energy calculations seem quite involved.
- Question: "Because purely inertial motions do not propagate vertically or horizontally, the frequency difference…" "To propagate, the waves must be somewhat super-inertial…" "Clockwise polarisation with depth indicates downward motion…"

Allen, S. E., Vindeirinho, C., Thomson, R. E., Foreman, M. G. G., & Mackas, D. L. (2001). Physical and biological processes over a submarine canyon during an upwelling event. Canadian Journal of Fisheries and Aquatic Sciences, 58(4), 671–684. https://doi.org/10.1139/f01-008

- Summary: An intense and short sampling of Barkley Canyon in July 1997 shows similarities to the Astoria Canyon off the coast of Washington, where summer periods of strong upwelling form that advect biological constituents, like zooplankton. These intervals of enhanced upwelling occur when the canyon depth mean currents are running towards the southeast in the summer, thanks to strong NW winds.
- Reading: Klinck (1996), Allen (1996), Hickey (1997); upwelling at canyons.
- Methods: A lot of good topographical and geographic information regarding Barkley Canyon in this paper.
- Methods: Can check for the characteristic summer upwelling currents both above and within the canyon, to support these findings, as well as comparative wind data.
- Methods: Buoy 46206 for wind data (seaward of Barkley Sound).

- Questions: This upwelling results in high concentrations of zooplankton above the canyon; could this be the harmonics in the w spectra near the surface?
- Questions: Is the Northeast Pacific Coastal Current the main source of the flow to the NW that is present for much of the year (Thomson)?
- Questions: Are hydrographic lines B and C still operational?
- Questions: What is the 24 sigma-t surface? Something to do with the mixed layer and pycnocline?

Martini, K. I., Alford, M. H., Kunze, E., Kelly, S. M., & Nash, J. D. (2013). Internal bores and breaking internal tides on the Oregon continental slope. In Journal of Physical Oceanography (Vol. 43). https://doi.org/10.1175/JPO-D-12-030.1

- Summary: Martini *et al* propose that non-linear internal bores are responsible for much of the internal tide dissipation on the Oregon continental slope, as they lead to vertical transport due to mixing. They provide evidence that bores have a periodicity of approximately 12h, potential phase locking to baroclinic tides, and increased dissipation rates.
- Reading: Carter (2002) "Intense, variable mixing...", canyons. Kunze (2012), canyons. Thurnherr (2005), canyons.
- Methods: Obtain a cross-section of local bathymetry.
- Methods: Look for evidence of upslope mixing due to internal bores incident on the shelf, by identifying a conversion of barotropic or incoming baroclinic tides to local internal tides, and phase locking with forcing.
- Methods: Identify slope angle and investigate reflection or scattering.
- Questions: Barotropic surface tides are 'depth independent', but is there diminishing effect with depth for generating baroclinic internal tides as the surface tides move water over irregular bathymetry?

Kunze, E., Mackay, C., Mcphee-Shaw, E. E., Morrice, K., Girton, J. B., & Terker, S. R. (2012). Turbulent mixing and exchange with interior waters on sloping boundaries. Journal of Physical Oceanography, 42(6), 910–927. https://doi.org/10.1175/JPO-D-11-075.1

- Summary: Well-stratified turbulent layers are found near the bottoms of submarine canyons, and are of an order of magnitude thicker than the well-mixed bottom boundary layers. This indicates that mixing efficiency above submarine canyons holds in the presence of internal wave generation or interaction with the irregular canyon topography. Furthermore, canyon topography is important to the strength of turbulent mixing, which varies over its structure. Up-canyon turbulence-driven transport occurs, where it contributes to greater mixing effects between the turbulent layer and interior. This all suggests that 1D interpretations of canyon mixing effects are inadequate for physical models.
- Question: Do more research into thermohaline circulation, as briefly discussed in class.
- Question: Do more research into abyssal sub-inertial currents, as one of the main energy sources for mixing in the ocean interior.
- Question: Find a better definition of 'fine-structure' as it applies to oceanography.
- Methods: Identify near-bottom stratified turbulent layers, with ADCP? Seems to be more accurate with CTD, as near-bottom data of ADCP is often compromised.

Carter, G. S., & Gregg, M. C. (2002). Intense, variable mixing near the head of Monterey Submarine Canyon. In Journal of Physical Oceanography (Vol. 32). https://doi.org/10.1175/1520

- Summary: Intense diapycnal mixing is found to occur in the Monterey Submarine Canyon, as compared to the open ocean, due to scattering and reflection of internal wave energy that focuses towards the head of the canyon, contributing to greater energy density and therefore turbulence (such as bores) in this region. This reflects research suggesting that interaction with canyon topography can more efficiently transfer energy to small scales than wave-wave interactions. The structure of the canyon (bottom and wall slopes, bends, width, depth, etc.) contributes to these effects, and different canyon regions experience greater turbulent effects during different periods of the tidal cycle (ranging from diurnal to spring/neap). As submarine canyons are a notable portion of continental shelves, they are

suggested to contribute a small but significant portion of the global internal tide mixing budget.
- Question: What are expendable current profilers (XCP)?
- Methods: Determine wall slope angles to check depth reliability of Axis ADCP data (up to lower 30% of depth unreliable for 'steep' sides).

Kunze, E. (2017). Internal-wave-driven mixing: Global geography and budgets. Journal of Physical Oceanography, 47(6), 1325–1345. https://doi.org/10.1175/JPO-D-16-0141.1

- Summary: Internal wave breaking contributes a significant portion of the global mixing budget (about 2.1 TW). Internal wave-wave interaction is investigated for finescale parameterisation of shear and strain and their contribution to this mixing, determined though a study involving about 30,000 CTD casts, globally. They found that internal wave generation generally increased over abrupt topography due to elevated strain variance, and that most of this mixing occurs in the upper 1000 m. Their estimations indicate that internal waves do indeed drive open and deep ocean mixing processes, as estimated energy budgets align within uncertainty with those expected.
- Question: What's the definition of finescale and/or microstructure?
- Methods: Energy budget identification (perhaps beyond the scope of this research?)
- Reading: J. A. MacKinnon, Z.-X. Zhao, R. Pinkel, J. Klymak, and T. Peacock, 2007: Internal waves across the Pacific. Geophys. Res. Lett., 34, L24601, doi:10.1029/2007GL031566.
- Reading: Alford, M. H., Girton, J. B., Voet, G., Carter, G. S., Mickett, J. B., and Klymak, J. M. (2013). Turbulent mixing and hydraulic control of abyssal water in the Samoan Passage. Geophys. Res. Lett. https://doi.org/10.1002/grl.50684

Robertson, R., Dong, J., & Hartlipp, P. (2017). Diurnal Critical Latitude and the Latitude Dependence of Internal Tides, Internal Waves, and Mixing Based on Barcoo Seamount. Journal of Geophysical Research: Oceans, 122(10), 7838–7866. https://doi.org/10.1002/2016JC012591

- Summary: Critical latitudes are important for tidal frequencies, as they can enhance the effects of prominent (diurnal and semidiurnal) internal tides in those regions. Essentially, diurnal tides are generated and are immediately resonant in these regions, trapping the energy poleward of this latitude and distributing energy into higher frequencies, such as the semi-diurnal tides, etc., consistent with non-linear internal wave-wave interaction theory. Observations indicate that critical latitudes are important to consider in analysis of internal wave/tide generation in a region.
- Question: Why do the internal waves get trapped poleward (this is probably in the paper somewhere, but I must have skimmed over it)?
- Methods: Critical latitude analysis for Barkley Canyon (I am not sure that it is relevant, as no other papers in the region have mentioned it, but I can still check).
- Reading: Jayne, S. R., & St. Laurent, L. C. (2001). Parameterizing tidal dissipation over rough topography. Geophys. Res. Lett., 28(5), 811–814. https://doi.org/10.1029/2000gl012044

Terker, S. R., Girton, J. B., Kunze, E., Klymak, J. M., & Pinkel, R. (2014). Observations of the internal tide on the California continental margin near Monterey Bay. Continental Shelf Research, 82, 60–71. https://doi.org/10.1016/j.csr.2014.01.017

- Summary: Northward bound internal tide energy flux is found to be in abundance off the coast of Monterey Bay, California, due to notable topographical features at Point Sur. Data were obtained using a network of platforms, XCP, and FLIP. Results were found to generally agree with models, though semidiurnal tides were more energetic than expected, and it is thought that smaller spatial scales are necessary to resolve certain internal wave properties in the presence of rough topography.
- Question: What are some significant regions of internal wave/tide generation near the VICS?
- Methods: Ensuring observations are long enough to avoid coastally trapped diurnal waves interfering with semidiurnal tides. This shouldn't be an issue with the ONC data.
- Methods: Identifying energy flux direction for internal tides, to identify where incoming waves are generated (seems difficult).

- Reading: Rainville, L., Pinkel, R., 2006. Propagation of low-mode internal waves through the ocean. J. Phys. Oceanogr. 36, 1220–1237.

Rainville, L., and Pinkel, R. (2006). Propagation of Low-Mode Internal Waves through the Ocean. Retrieved from http://journals.ametsoc.org/jpo/article-pdf/36/6/1220/4483319/jpo2889_1.pdf

- Summary: To better understand the baroclinic tides and their generation, propagation, and dissipation in the oceans, a model was developed to better account for global processes that would affect internal tides and applied to observations near the Hawaiian Ridge. Their findings help to identify sources of apparent energy loss in internal tides, such as phase modulation and topographic drain. Internal wave/tide propagation speeds are estimated for various modes, and baroclinic 'shoaling' regions are identified to indicate regions of enhanced internal wave activity. Additionally, ray equations are derived and associated with mesoscale currents to create a 'complete' picture of baroclinic propagation. In the end, they determine that a WKB approach to a modal evaluation of internal wave propagation is most effective for realistic results.
- Question: What exactly is phase modulation? I do not understand this concept that well, and it wasn't described in detail.
- Method: A modal analysis of generated waves in the canyon compared to on the plateau could be an interesting comparison.
- Reading: Nash, J., E. Kunze, J. Toole, and R. Schmitt, 2004: Internal tide reflection and turbulent mixing on the continental slope. J. Phys. Oceanogr., 34, 1117–1133.

Nash, J. , Kunze, E., Toole, J. , & Schmitt, R. (2004). Internal Tide Reflection and Turbulent Mixing on the Continental Slope. Retrieved from http://journals.ametsoc.org/jpo/article-pdf/34/5/1117/4470231/1520-0485

- Summary: To better understand the eventual dissipation of low-mode internal tides, observations were made at a steep slope off the coast of Virginia in Spring 1998, where the incoming flux is seemingly reflected back out at higher modes. Various explanations are given for unusually enhanced mixing near the base of the slope, a likely culprit being early reflection of incoming baroclinic tides down to this region. The incoming low-mode energy is though to be from a remote source of M2 internal tide generation that propagates to this slope, where it is reflected and scattered off the near-critical slope as higher-mode waves. These waves travel about 100km before dissipating, and could be an important energy transfer process to drive turbulent mixing in the ocean.
- Question: How do you tell the difference between barotropic and baroclinic tides from velocity data? So far in these papers it's just been stated as obvious. Does it have something to do with a shift in phase, or period?
- Method: Identify incoming barotropic tides to compare with the criticality of the slope near Barkley Canyon, to see if enhanced mixing could occur in this region.
- Reading: Gilbert, D., 1993: A search for evidence of critical internal wave reflection on the continental rise and slope off Nova Scotia. Atmos.–Ocean, 31, 99–122.

Alford, M. H., Mackinnon, J. A., Zhao, Z., Pinkel, R., Klymak, J., Peacock, T., … Peacock, T. (2007). Internal waves across the Pacific. Geophys. Res. Lett, 34, 24601. https://doi.org/10.1029/2007GL031566

- Summary: This paper seeks to better understand the propagation of northward internal tides (semidiurnal) from the Hawaiian Ridge, and how they would be affected by parametric subharmonic instability (PSI) at the critical latitude of 28.8 degrees. PSI is a method for generating internal waves through energy extraction from internal tides, and should be detectable as a form of energy loss in the barotropic tides in this region. Though there were energetics associated with PSI detected at this latitude, it was also discovered that the tides propagated further north with less discernible energy loss than was expected. For now, spreading and PSI together can account for attenuation of the baroclinic semidiurnal tide northward of the Hawaiian Ridge.
- Question: How does PSI work, exactly? Shouldn't be too difficult to find this in a textbook or paper.

- Method: Again, rotary spectral analysis seems essential. I need to get back to coding this weekend and finish that.
- Reading: Kunze, E., L. Rosenfield, G. Carter, and M. C. Gregg (2002), Internal waves in Monterey Submarine Canyon, J. Phys. Oceanogr., 32, 1890– 1913.

Gilmour, A. (1987). A preliminary rotary spectral analysis of inertial currents... New Zealand Journal of Marine and Freshwater Research, 21, 353–357. https://doi.org/10.1080/00288330.1987.9516231

- Summary: The benefits and limitations of rotary analysis are discussed and demonstrated in a case off of the coast of New Zealand, where a rotary analysis indicates the notable presence of intertial frequencies, to be studied further.
- Importance: Provides a good example of the pros and cons of rotary analysis, and a practical application with results. This paper is beneficial for anyone doubting the efficacy of rotary analysis.
- Questions: I still struggle with the actual *how* of performing a rotary spectral analysis. I'm certainly close, but it would be nice if one of these papers actually gave a few equations that they used.
- Useful methods: Rotary spectral analysis, in process.
- Personal opinion: A good paper for understanding the theory of rotary spectra, but a bit short, and somewhat qualitative.
- Additional reading: Gonella (1979)

Gonella, J. (1972). A rotary-component method for analysing meteorological and oceanographic vector time series (Vol. 19). Pergamon Press.

- Summary: Gonella describes a method for calculation the counter-rotating components of a velocity vector, and shows an example of applying this theory to resolving Ekman spiralling, among other derivations of coherence, orientation, etc.
- Importance: A critical work in defining the use of rotary spectral analysis, and providing an example of its application.
- Questions: A bit difficult to follow the notation, which is where I believe I'm making a mistake.
- Useful methods: Rotary spectral analysis, in process.
- Personal opinion: A very good chapter on spectral analysis, but the notation is confusing.
- Additional reading: Lamb, Hydrodynamics (textbook). Check for rotary information.

Thomson, R. E. (2014). Data analysis methods in physical oceanography (Third). Oxford, UK: Elsevier.

- Summary: Derivation of the rotary spectral components, autocorrelation, etc. as they pertain to an analysis of velocity data for physical oceanography.
- Importance: Rotary spectral analysis provides insight into the presence of horizontal circulation, and can reduce the effects of inertial rotation when creating power spectra, to better highlight tidal constituents.
- Questions: Once again, the notation is difficult to follow, and I'm wondering why it changes between every source that deals with rotary spectral analysis.
- Useful methods: Rotary spectra.
- Personal opinion: Well done, and the most clear of all of the sources regarding this type of analysis. Still confuses me a bit, however.
- Additional reading: None from this chapter, as I believe I finally have the rotary spectra working correctly.

Gregg, M. C., & Kunze, E. (1991). Shear and strain in Santa Monica Basin. Journal of Geophysical Research, 96(C9), 16709. https://doi.org/10.1029/91jc01385

- Summary: Acoustic and CTD data were collected over two days in 1989 at Santa Monica basin, for an analysis of internal wave activity to show that shear and strain are intensified as compared to the open ocean GM76 models, contributing to enhanced diffusivity.
- Importance: Confirmed contemporary assumptions that enhanced internal wave activity in coastal

waters is related to higher than expected diffusivity, and provides an excellent resource for GM spectra comparisons and parameters.

- Questions: There are many, but I will limit it to: what is the benefit of plotting wavenumber instead of frequency in Hz (frequency seems much more intuitive, to me)?
- Useful methods: Everything in this paper seems useful, particularly the GM appendix. I will refer back to it, regularly.
- Personal opinion: Excellent. Overly comprehensive in their analysis, but that isn't a bad thing.
- Additional reading: D'Asaro 1984, Wind forced internal waves... Hickey 1989, Variability in two deep... G&M 1975, Space-times scales of internal waves... Cairns & Williams 1976, Internal wave observations...

Hamann, M. M., & Alford, M. H. (2020). Turbulence driven by reflected internal tides in a supercritical submarine canyon in: Journal of Physical Oceanography - Ahead of print. Retrieved December 14, 2020, from Journal of Physical Oceanography website: https://journals-ametsoc-org.ezproxy.library.uvic.ca/view/journals/phoc/aop/JPO-D-20-0123.1/JPO-D-20-0123.1.xml?rskey=wr7skm&result=1&tab_body=pdf

- Summary: An analysis of incident mode-1 semidiurnal tides in La Jolla Canyon System shows that reflection and scattering by the supercritical canyon walls (and up-canyon axis)can lead to higher mode waves that can cause elevated mid-depth dissipation, in addition to the near-bottom elevated turbulent dissipation that is expected.
- Importance: Suggests a new process in canyon regions that could contribute to mixing and internal wave dissipation in ways that weren't previously considered.
- Questions: Are there specific criteria for distinguishing between slope canyons and shelf canyons, or is it a qualitative judgement call?
- Useful methods: Tidal filtering and a comparison of wavelength to canyon length, shape, and the criticality of the slope of the canyon walls and axis along its length.
- Personal opinion: Alford's papers are always very clear, and the analysis process explained in just the right amount of detail. This will be very useful for my own tidal analysis.
- Additional reading: Hotchkiss and Wunsch 1982, internal waves in canyons